Dear readers,

With this tenth issue of FAST it is an opportune moment to think about what FAST is and where its future lies. For those of you who are unlucky enough not to have a copy of the first issue you may not know that the title is an acronym for Flight, Airworthiness, Support and Technology and in fact these are the subjects which are to be found in this magazine.

In this cost conscious age of communications where paper passes across our desks in ever increasing quantities, much of which is not read, it is necessary for the publishers of a magazine such as this to do their utmost to make sure that it is published only when there is a story to tell, and when it arrives on your desk you are enticed to open it, and then read it. And having read it, found the information useful.

We believe that FAST is a good vehicle to pass on information which supplements that found in the official maintenance and operational documentation. I thank you and wish you a few minutes interesting reading.

Yours sincerely,

Gérard Blanc
Product Support
Senior Vice President
2

EVOLUTION OF HYDRO-MECHANICAL COMPONENTS IN THE FLIGHT CONTROL SYSTEM
Uwe Eggerling

8

A320 FULL SCALE FATIGUE TESTING
Anthony Hitchcock

14

OPERATIONAL RELIABILITY IMPROVEMENT PROGRAMME - SPURIOUS SMOKE WARNINGS ON A300 AND A310 -
Achim Krapp

19

MAINTENANCE PROGRAMME DEVELOPMENT
Richard Cutler

25

MAINTENANCE AND REPAIR - DO YOU NEED HELP?
Michel Patry

28

ENGINE BLEED AIR SYSTEM ON A300-600 AND A310
Francois Roson

31

FIELD SERVICE REPRESENTATIVES

32

STRUCTURAL TESTING - PART 2

The articles herein may be reprinted without permission except where copyright source is indicated, but with acknowledgement to Airbus Industrie. Articles which may be subject to ongoing review must have their accuracy verified prior to reprint. The statements made herein do not constitute an offer. They are based on the assumptions shown and are expressed in good faith. Where the supporting grounds for these statements are not shown, the Company will be pleased to explain the basis thereof.

Publisher : Airbus Industrie, Product Support Directorate
1, rond-point Maurice Bellonte, 31707 Blagnac Cedex, France
Telephone +33 (61) 93 33 33 Telex AIRBU 530526 F Telefax 33 (61) 93 44 24
Editor : Denis Dempster
Graphic Design and Artwork : Agnès Laconbe
AIRBUS INDUSTRIE © 1990
EVOLUTION OF HYDRO-MECHANICAL COMPONENTS
IN THE FLIGHT CONTROL SYSTEM

by Uwe EGGERLING
Airbus Product Support
Supervisor Flight Control Systems

In the twenty years since the start of the A300 programme there has been constant evolution in the design of Airbus structures and systems. This article describes the improvements which have evolved in some of the components in the flight control systems of the A300, A310 and A320.

The advance of technology which led to the improvements and advantages achieved by fly-by-wire, such as computerisation and weight saving, has also continued in the design of equipment and choice of modern materials. This has benefited the performance and maintainability of the hydro-mechanical components in the flight control system. Some typical examples follow.
TAILPLANE TRIM ACTUATOR POWER GEAR TRAIN

A300

The power gear train of the tailplane trim actuator installed in the A300 is driven by three hydraulic motors which are coupled by a torque summing gear. This motor and gear arrangement becomes sensitive when the three motors are not synchronized, i.e. two motors are acting against the third. Motor synchronization can only be performed using workshop facilities.

De-synchronization of the hydraulic motors, either alone or combined with other faults, may set up internal loads in the power gear train and cause abnormally high pressure surges in the hydraulic manifolds.

This sequence of events has been responsible for several findings during testing and in service. These findings include:

- cracked hydraulic blocks,
- damaged static seals,
- broken gears,
- damaged needle bearings.

Several improvements were introduced such as better lubrication of needle bearings and re-distribution of torque in the power gear stage by introducing a lost motion gear assembly in the output gear train. Also a time between overhaul of 12,500 flight hours was assigned.

A310

The A310 has only two hydraulic motors to drive the tailplane trim actuator. Two motors can be coupled by a speed-summing differential gear, thereby avoiding difficulties resulting from de-synchronization and so achieving the full fatigue life objective.

A300-600/A320

Due to good in-service experience the same motor and gear arrangement used in the A310 was installed in the A300-600 and was applied to the A320 (figure 1).

FLAP DRIVE SYSTEM

A comparison of the flap drive system installed in the A300 with those installed on the A310 and A320 shows how much these systems have evolved.

A300

On the A300 (figure 2a), no-back devices are installed in each screwjack to ensure irreversibility of the flaps in the event of disconnection of the drive system. The no-back device comprises two brake discs which act during extension and retraction of the flap system.

A maintenance task has been introduced which checks the no-back devices for backlash and indicates an abnormal wear on the brake discs, which could otherwise remain undetected. Torque
limeters are also installed in each screw- 
jack to protect the flap system from 
overload but there is no external indi-
cator to show when a torque limiter has 
operated.

**A310**

With the introduction of a bi-directional 
wing tip brake on the A310, controlled 
by the slat/flare control computer it was 
possible to delete the no-back device 
without losing the no-back protection. 
Thus the screwjack itself was made less 
complex, improving reliability. In addi-
tion an indicator was provided in each 
screwjack to give a quick indication of 
which screwjack-torque-limiter was in-
volved in the event of a flap system lock-
out. This significantly eases trouble 
shooting.

**A320**

For the A320 the slat and flap drive 
system was completely redesigned. The 
screwjacks were replaced by rotary gear 
actuators (figure 2b). Once again the 
mechanical units have been simplified, 
with the following main advantages:
- the actuator is lubricated with grease 
  instead of oil, for more efficient sealing,
- it is grease-packed for life, so no 
  maintenance action is required to check 
  and top-up lubricant levels,
- the sealing is more efficient as only 
  simple seals around a shaft are used and 
  not the complex curved and cornered 
  seals in the ball nut.

Information from maintenance plan-
ing documents, in table 1 below, shows 
the significant reduction in maintenance 
requirements which have been achieved.

**SEALING IMPROVEMENTS**

A ball-screw-nut assembly requires that 
for every movement of the nut along the 
screw a thin film of grease remains on 
the screw shaft, i.e., an allowable grease 
loss is needed. The nut and seal are 
therefore designed that enough grease 
is available for lubrication of the nut and 
dispersion along the shaft between the

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Task</th>
<th>Interval</th>
<th>Men</th>
<th>Man hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>A300</td>
<td>Check no-back discs for backlash</td>
<td>12000 landings</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Lubricate ball-screw-nut</td>
<td>3 A check</td>
<td>1</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Check oil level in screwjack</td>
<td>C check</td>
<td>1</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>Check oil level in down-drive gearbox</td>
<td>C check</td>
<td>1</td>
<td>6.0</td>
</tr>
<tr>
<td>A310</td>
<td>Operation test of wing tip brake</td>
<td>2000 flight hours</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Lubricate ball-screw-nut</td>
<td>2 A check</td>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Check oil level in screwjack</td>
<td>C check</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>A320</td>
<td>Operation test of wing tip brake</td>
<td>3500 flight hours</td>
<td>2</td>
<td>0.6</td>
</tr>
</tbody>
</table>
during lubrication but no water in. As aircraft never fly under laboratory conditions this new seal arrangement was tested on aircraft in service, which allowed further amelioration, such as reduction of the opening pressure of the non-return valve to ease greasing.

In other areas it was found that cracking of rubber seal material may occur due to ozone attack and contamination by phosphate ester hydraulic fluid. The performance and reliability of the equipment affected by seal deterioration was improved by introducing a new seal material called fluorosilicone which is ozone-resistant and has an improved resistance to contamination from hydraulic fluid (figure 3).

**Figure 3**
A310 flap screw jack

- Jack head
- Fluorosilicone shaft seal
- Ball nut
- Ball nut seal
ADVANCED AIRCRAFT LUBRICANTS

Another area of Airbus Industrie activity is improving the performance and reliability of aircraft components by encouraging the development of advanced lubricants specifically for aviation. There is an increasing number of instances where the ability of lubricants to provide adequate lubrication and corrosion protection on aircraft in service is either in question or has been proven inadequate. Reports have been received of corrosion, disintegration of rollers due to moisture ingress and black acid etching. Also migration and washing out of grease is a well-known finding which can lead to bearing seizure.

When a lubricant becomes emulsified with water, apart from allowing corrosion, ice can form, significantly reducing equipment performance. Because of this, Airbus Industrie has established a working group consisting of specialists from vendors, a lubricant manufacturer and Airbus Industrie and its partners. The aim is to evaluate new types of grease for specific aviation applications rather than using a general purpose lubricant which will be a compromise in all cases.

The parameters around which a suitable product could be designed are as follows:

- good corrosion resistance,
- good water resistance,
- low evaporation loss,
- high oxidation resistance,
- low temperature capability,
- satisfactory load bearing capability,
- satisfactory operational envelope.

Resulting from the efforts of the working group, a lubricant was made available and tested by several airlines. It was concluded that good anti-corrosion properties must be retained but the low temperature torque of this grease should be further reduced. This has been done and the improved grease is now under airline evaluation, which is expected to be complete by mid-1990.

FLAP SYSTEM CARBON DRIVE SHAFTS

With each new aircraft project Airbus Industrie has introduced more and more carbon fibre composites in the structure to reduce weight, hence improving aircraft performance. The introduction of carbon fibre composites in flap drive system components is being investigated, replacing the steel drive shafts in the flap transmission system by carbon fibre shafts. The advantage would be a weight saving of about 35 kg per aircraft for the A310. One A310 aircraft is equipped with flap transmission shafts made from carbon fibre composite, and service testing is in progress.

ROLLER BEARINGS

Teflon-lined bearings are installed at various places on the flight control system. There have been reports that the teflon migrates, resulting in increased backlash and wear, and, depending on their location, to aircraft vibration during flight. It is believed that the debonding of the teflon liner comes from a combination of vibration and pollution in an environment where a mixture of hydraulic fluids and water is present and perhaps particular load conditions.

Contacts have been made with a bearing manufacturer who uses special techniques to spray a self-lubricating liner called Karon on the metallic surface, and to obtain better adhesion than for the bonded teflon liner. Although good experience was reported on other aircraft types, Airbus Industrie decided to perform an in-service evaluation on an A310 before issuing a recommendation to its operators. The evaluation exercise is planned to last until mid-1990 followed by a detailed workshop investigation of the bearings after removal.

SERVO VALVE JAM DETECTION SYSTEM

On the A300 and A310 the hydraulic servo actuators operating the aileron, rudder and elevator surfaces are equipped with a control valve jam-detection system which monitors possible malfunction of the valves (figure 4).

In-service experience revealed that this system was causing more false warning indications than real control valve jam occurrences, which happen very rarely. It was also reported that when a primary control surface was deflected on the ground by a gust of wind when the actuators were not hydraulically powered, a false jam warning could occur when the system was switched on.

Such an occurrence could lead to delay and unnecessary trouble shooting. The system was therefore modified to recognise such false warnings. A reliability analysis of such a jam system for the A320 has shown that it is not required, thus avoiding erroneous cockpit indications and saving on maintenance (figure 4).

RUDDER CONTROL SYSTEM

Maximum rudder deflection in flight is limited in relation to airspeed, to ensure that maximum rudder movement is always less than the deflection which would induce limit loads to the structure. The unit installed in the rudder control system providing this limitation function was changed from the A300 to the A310 and again to the A320 and can be taken as an example of how evolution in advanced flight control design leads to more simple equipment, improving reliability (figure 5).
A300 variable lever arm unit

A hydro-mechanical unit consisting of a pivot rod and lever linkage actuated by two electro-hydraulic actuators. Depending on the aircraft speed the actuators modify the lever linkage arrangements and limit the output to the rudder servo actuators.

- Electro-hydraulic actuator

A310 variable stop unit

One electro-mechanical actuator operates an articulated lever shaped to limit the rudder control stops according to the speed. There are no hydraulic components and the mechanism has been simplified compared with that on the A300.

- Frame
- Variable stop actuator
- Lever assembly
- Drive shaft
- Variable stop transducer unit

A320 rudder travel limitation unit

Two electric motors, each driving a screw via a reduction gear, position two nuts used as limiting stops for the rudder servo actuator control. This is a compact unit, once again simplified compared with previous Airbus types.

CONCLUSION

From the earliest design phase of an Airbus product, a process of constant improvement is applied and continues right through the product's service life, ensuring maximum cost-effective efficiency.
Imagine you are seated in the cabin near to the wing, waiting for take-off on a windy day...

As your aircraft gets airborne, you feel the movement caused by the gusty wind, you see the wing flexing up and down and perhaps you think to yourself "I wonder how long that wing (and perhaps some of the other parts I can’t see!) will keep bending like that?". Well, you can continue your flight assured in the knowledge that each Airbus aircraft type is twisted, bent, shaken and rattled millions of times before the first one goes into service.

That is "Full-Scale Fatigue Testing".

- Fatigue testing
- Static testing
- Fatigue and static testing
In Europe, all aircraft manufacturers fulfill a certification requirement to test a representative structure of any new aircraft for the equivalent of its design life.

Airbus Industrie does a great deal more, as you will see shortly. It has an enormous wealth of experience in this field, dating back to the earliest days of civil jet aircraft operation.
Back in the early seventies, Airbus' first product, the A300, was subjected to this rigorous test programme, as was the A320 more recently. The Airbus partner companies involved in all these programmes also have considerable experience and knowledge from their individual aircraft projects. All this experience was put to full use in fatigue testing the A320. Quite apart from the legal, certification aspect, full scale structural fatigue testing, in the case of the A320 serves a number of important purposes.

**PURPOSE**

- The test airframe is used to justify satisfactory structural behaviour throughout the expected life of the aircraft.
- The test is used to prove the design aim. It is also of prime importance when developing derivatives with higher gross operating weights.
- It is used to establish the structural inspection program as defined in the Maintenance Review Board (MRB) document.
- The test programme allows rapid identification of any weak points in the primary structure. Depending on when and where any damage occurs Airbus Industrie will immediately decide on the corrective action to be taken. This could be anything from a complete modification programme for aircraft in production, with in-service retrofit, to an adjustment of the inspection programme.

In the case of the A300B2/B4, to cite a typical example, the findings from the latter part of the test program were used to develop and justify the Supplemental Structure Inspection Programme (SSIP).

**TEST PROGRAMME**

As mentioned earlier, Airbus Industrie has done more than just satisfy a certification requirement. The A320 test airframe was subjected to a total of 120,000 simulated flights, fully representative of how an aircraft in service actually operates. This in fact is the equivalent of two and a half aircraft lives, based on the design economic repair life of 48,000 flights.

Airbus Industrie's partner companies were deeply involved in the test programme, just as they were for the A300 and A310. This led to an unusual, innovative but extremely efficient and rational way of testing.

Normally, one would expect a complete aircraft to be assembled, installed in a giant test rig and then cycled. Airbus Industrie decided on a method called "multi-section" testing. The fuselage test specimen was split into three major parts, each with an overlap to the adjacent part. This method of testing has distinct advantages: it is far less complex than a complete airframe, and it enables testing to continue on the remaining sections should damage appear on one of them. It also means fewer compromises in the load spectrum, and finally, the test programme can run much faster.

Several major components are omitted from the test specimens, for example the pylons and the main and nose landing gears. These are replaced by dummy components, because only the loads of these items need to be introduced into the test airframe. However, because all major parts of the aircraft need to be tested, these components undergo their own specific fatigue and static tests.

Now to the test programme itself. Each of the major sections is installed in a test rig. If we take the specimen containing the fuselage centre section and wing, the test rig consists basically of numerous hydraulic jacks placed at various wing and fuselage stations as load introduction points. The fuselage centre section is closed at each end and subjected to cabin pressure (DP). To avoid the need for vast quantities of compressed air, and thus slower cabin cycling times, the fuselage is filled with...
expanded polystyrene blocks. The whole system is controlled through a computer program, into which all the “fatigue mission” data is fed.

**FATIGUE MISSION**

So what constitutes a fatigue mission? This is quite simply a typical flight from engine start and taxi-out, through climb, cruise, descent, landing and taxi-in (figure 1). This typical “flight” is repeated throughout the test programme, each flight taking about five minutes to simulate. Just to make it more interesting, the occasional severe wind gust and “firm” landing and other such loads, that statistics show could occur during the operational life of the aircraft, are also fed in. For the A320-100, the flight simulated is of one hour duration at a typical take-off weight (TOW) of 56 tonnes and a cabin pressure of 556 mb (8.06 psi). A typical A320-200 flight with a TOW of about 58 tonnes is similar. These weights are typical every day take-off weights, which are less than the maximum permissible figures.

**THE TEST**

The aim of the test was to cycle the airframe for 120,000 simulated flights. However, it was not just a question of throwing a switch and then allowing the
test to proceed without further attention. The programme consisted of two main phases. The first, up to 60,000 flights was to simulate more than one life before certification, with the aircraft behaving normally. From 60,000 up to the end of the programme at 120,000 flights, there was the crack propagation phase. This enabled the design and fatigue specialists to observe the behaviour of the aircraft with natural and artificial cracks present. This is the damage tolerance part of the test, the most important part of the whole programme. At various stages in the life of the specimens, the tests were stopped and the structure was inspected to locate any damage that occurred, and where necessary to repair it (or even incorporate a modification). These inspections are also very useful to the specialists in non-destructive testing (NDT) as it helps them to develop the inspection methods which accompany the structural inspection programme for the aircraft in service.

**TEAR DOWN**

However, once the 120,000 flight have been completed, it is not yet the end of the story and there still remains a lot of work to be done. A particular part or specimen may be subjected to further residual strength testing, or as in the case of a fuselage section, further ΔP cycling. Then the specimens are dismantled and subjected to detailed NDT and laboratory examination. This is the part of the test known as the “tear-down”.

At the end of all this testing, Airbus Industrie has an extremely accurate picture of how the aircraft will behave in service and can complete the MRB inspection programme accordingly.

**REPERCUSSIONS**

Everything mentioned so far in this article gives a picture of the ideal situation. There are however some realities which Airbus Industrie as a manufacturer and the operators need to consider. Sometimes, even with the best will in the world, something breaks. If this happens very late in the life of the specimen, it generally has no great effect on the aircraft. If the damage occurs early, or is significant, then something has to be done about it. In this respect the A320 has performed extremely well, having benefitted considerably from previous experience on A300/A310.

Of 150 or so findings to date the vast majority were of a minor nature, not safety-related and requiring no significant design changes. Of those findings, some were discovered early in the programme and were corrected before delivery of the first production aircraft. Some of those findings found later will require retrospective action on aircraft already in service, as well as those on the assembly line.

All findings are thoroughly analysed to see if there are any implications on the aircraft programme. Should this be the case, a decision is taken on whether or not to raise a modification, and if so, whether the modification should be retrofitted. It has always been Airbus Industrie policy to offer customers a choice, so if a modification Service Bulletin is to be issued, Airbus Industrie may well consider an alternative inspection programme allowing the operator to decide which course of action to take. There are cases where there is no alternative: this happens when the time needed to perform the inspection is the same as or longer than that needed to retrofit the modification.

To show how this works, a typical finding from the test programme is shown in figure 2. In this example, cracking was found in the belly fairing structure, initially in a stiffener at approximately 38,000 test flights, followed by cracking of the shear plate at 41,700 test flights. Analysis of these findings showed the necessity for a modification and it was decided to make a production change.
from aircraft MSN 093, with a retrofit modification by Service Bulletin on in-service aircraft. This Service Bulletin will recommend installation of a new titanium stiffener and shear plate at 12,000 flights. This figure is derived from the use of a scatter factor to relate the test findings to a fleet of in-service aircraft. In this example, an alternative inspection will not be proposed as it is likely to take the same number of man-hours as the modification, and therefore be an unnecessary burden.

To date, Airbus Industrie has identified some thirty modifications for which modification Service Bulletins will be issued. At the same time nineteen alternative inspection Service Bulletins have been decided upon. As the teardown programme has not yet been completed and analysed, it is possible that further Service Bulletins will follow.

Where possible, Airbus Industrie has attempted to set the thresholds for retrofits and/or inspections to match the target for major maintenance layovers, which are set at 20,000 flights or eight years. This has not been possible in a few cases and at the time of writing, there are about six Service Bulletins which will need to be retrofitted before 12,000 flights have been reached.

**CONCLUSION**

The foregoing has set out the background and the results of the A320 full scale fatigue test programme.

From the operators’ point of view an important consideration is the repercussions of the retrofit programme on the aircraft in service. Towards the end of 1990, Airbus Industrie will hold a conference in Toulouse on the subject where the findings and the details of the fatigue test programme will be presented and discussed.

However the most important part of this from all points of view is the fact that the A320 has already been tested to destruction and shown that it will survive many more flights than any operational A320 will see in the next twenty years.
Fumes and odours in an aircraft cabin can be very upsetting for the passengers and crew and very disruptive to airline operations. The origins and the cures are known. By following the advice given in this article, the frequency of their occurrence will greatly diminish.
GENERAL

Spurious smoke warnings in the avionics, battery and cargo compartments have been triggered in flight and on the ground during in-service operation. The majority of these warnings have been caused by contaminated air circulating in these compartments. The contamination is generated by various types of servicing fluids, grease and also external fumes or dust which penetrate into the air conditioning and the avionics compartment air-extraction system. Only on very rare occasions have cases been recorded where smoke warnings were triggered by a real fire or combustion or carbonization of aircraft components or materials. Therefore, by applying proper maintenance actions and preventive measures, the risk of spurious smoke warnings, causing passenger discomfort and costly ground and flight interruptions, can be significantly reduced.

ORIGIN

An evaluation of the in-service reports dealing with operational interruptions, i.e., delays, cancellations and air turn backs, revealed that there are two main categories triggering the smoke warnings:
- air conditioning contamination
- smoke detector sensitivity.

In the following, the topics of each category are discussed. The applicable Service Information Letters and Service Bulletins are listed in tables 1 and 2.

AIR CONDITIONING CONTAMINATION

Most warnings are attributable to this category which includes the air conditioning ducts, conoscer bags and the air-extraction system for the avionics compartment.

The identified sources of contamination are:

- APU oil,
- engine oil,
- hydraulic fluid,
- miscellaneous.

It should be noted, that following a corrective action such as repair of a leak, the decontamination procedure described in this article must be carried out.

APU OIL

External and internal APU oil leaks, contribute to the contamination of the air ducts. Whenever oil leaks into the APU compartment, the oil has a tendency to flow to the left APU access door. As the oil accumulates it escapes to the outside, then to the APU air intake where it is ingested and blown into the air-conditioning ducts. Service Bulletins are available which recommend the repositioning of the APU compartment drain mast from the right to the left access door as shown in figure 1, together with the installation of an additional barrier and sealing strip.

Table 1

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Service Information Letter</th>
<th>Effectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Avionics or battery spurious smoke warnings</td>
<td>SIL 26-015</td>
<td>All</td>
</tr>
<tr>
<td>APU</td>
<td>Isolation of bleed valve during cleaning</td>
<td>SIL 49-017</td>
<td>All</td>
</tr>
<tr>
<td>Hydraulic</td>
<td>Avoiding contamination</td>
<td>SIL 29-020</td>
<td>All</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Service Bulletin</th>
<th>Effectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>APU</td>
<td>Repositioning drain mast</td>
<td>Airbus SB A300-49-040</td>
<td>A300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Airbus SB A300-49-6006</td>
<td>A300-600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Airbus SB A310-49-2009</td>
<td>A310</td>
</tr>
<tr>
<td>APU</td>
<td>Improved low oil pressure switch</td>
<td>Garrett GTCP 331-49-5706</td>
<td>A310/A300-600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Garrett GPSON 49-93-0403</td>
<td></td>
</tr>
<tr>
<td>APU</td>
<td>Improved compressor seal</td>
<td>Garrett GTCP 331-49-5499</td>
<td>A310/A300-600</td>
</tr>
<tr>
<td>APU</td>
<td>Improved gearbox pressurisation</td>
<td>Garrett GTCP 331-49-5565</td>
<td>A310/A300-600</td>
</tr>
<tr>
<td>Engine</td>
<td>Oil leakage</td>
<td>PW JT9D-7R4 72-363/287</td>
<td>PW JT9D-7R4</td>
</tr>
<tr>
<td>Hydraulic</td>
<td>Air filters for reservoir</td>
<td>Airbus SB A300-29-080</td>
<td>A300s below MSN 173</td>
</tr>
<tr>
<td>Battery</td>
<td>Deletion of detector</td>
<td>Airbus SB A300-26-6015</td>
<td>A300-600</td>
</tr>
<tr>
<td>smoke</td>
<td></td>
<td>Airbus SB A300-26-2014</td>
<td>A310</td>
</tr>
<tr>
<td>detector</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1

APU compartment access doors

- Drain mast

Unmodified access door

FWD

Modified access door

FWD

FAST / NUMBER 10 15
Major sources of contamination:

- Anti-icing fluid
- APU internal and external oil leaks
- APU cleaning procedure
- Contaminated cargo compartment smoke detectors
- Cargo loading vehicles exhaust fumes
- Frequent plant and livestock transportation
Triggering spurious smoke warnings

- Overfilled hydraulic reservoirs
- Contaminated coalescer bag
- Engine oil leaks
- Contaminated avionic and cargo compartment smoke detectors
- Air starter internal oil leaks
- Engine oil leaks Anti-icing fluid
- Ground cart fumes
There is also the risk that the fluids applied during cleaning of the APU compressor will contaminate the system. As a consequence a Service Information Letter was issued in March 1987 which calls for bleed line isolation during the cleaning procedure.

One of the origins of external APU leaks is the low oil pressure switch. An improved switch having an one-piece body with welded seams has been developed and is available.

Internal oil leaks of the APU load compressor can be avoided by incorporation of an improved APU compressor seal and the gearbox pressurisation system can also be improved.

ENGINE OIL

Pratt and Whitney JT9D-7R4 engines experienced oil wetting and/or drainage from the engine nose spinner as a result of seal leakage at the number four bearing. Residual oil accumulates in the spinner and can work its way into the engine air stream thus contaminating the air conditioning system. A Pratt and Whitney Service Bulletin has been issued calling for installation of an improved bearing seal.

HYDRAULIC FLUID

Another potential risk of air duct contamination comes from the penetration of hydraulic fluid. This may occur in particular if the aircraft is parked for more than thirty-six hours and the air pressure of the hydraulic reservoirs has dropped. If the column of hydraulic fluid in the return lines from the components in the tail of the aircraft creates a pressure higher than the air pressure in the reservoirs, the fluid level will increase. If in such a case the check valves of the reservoir air pressurisation lines are not tight, fluid enters into the air-conditioning system. Overfilling of the reservoirs during servicing may lead to the same condition. Procedures to avoid this type of contamination are described in a Service Letter Information.

A300s below MSN 173 should also have air filters installed in the reservoir air pressurisation system to eliminate leaking check valves due to entry of dust and sand.

MISCELLANEOUS

Grease

During engine or APU installation the use of grease on components such as duct flanges and clamps is not recommended unless specified in the appropriate documentation. Observance of this rule prevents fumes and odours from forming.

External sources

Smoke warnings, in particular for cargo compartments during aircraft ground or transit time, are in almost all cases triggered by the entry of external fumes into the cargo and avionics compartments. Therefore, the proper positioning of ground vehicles according to the facility planning manual should be followed. Vehicles supplying ground air also should be frequently inspected to ensure that any internal oil leaks which they may have do not contaminate the aircraft systems.

Anti-icing fluid

During the winter season an accumulation of warnings stemming from the application of anti-icing fluid before aircraft departure may be noticed. The procedures indicated in AMM 12-31-11 should be adhered to, to prevent entry of the fluid into the engine and APU air intakes.

DECONTAMINATION PROCEDURES

Whenever the air conditioning system has been contaminated by fluid the decontamination procedure must be carried out following the repair of the leak. If this is not followed, the residual fluid and grease inside the ducts and in the coalescer bags will cause continuous warnings during the subsequent flights. An increasing number of operational interruptions will be the consequence.

The detailed procedures described in AMM 21-51-00 consist mainly of:

- blanking off of avionic bay cold air ducts,
- operating the system by means of the APU in full COLD and HOT
- replacing/cleaning coalescer bags as required (AMM 21-51-16 refers).

SMOKE DETECTOR SENSITIVITY

Cargo holds

Contamination of the detector cells with dust and condensation increases sensitivity and thus the risk of spurious warnings. Therefore to ensure reliable functioning of the smoke detectors, cleaning and checking should be performed in accordance with CMM 26-11-15 every “2C” check. However, experience has shown that there is a need to increase this frequency for operators who fly in a dusty environment and/or often transport livestock or goods releasing high humidity such as plants.

BATTERIES

Service Bulletins are available to eliminate spurious battery smoke warnings. They recommend the deletion of the battery smoke detector and the associated warning light. This system simplification does not degrade the protection capability. The existing overload and thermal protection provided by the charge controllers and the battery ventilation is adequate.

CONCLUSION

The various sources of contamination of the air-conditioning system are well identified and corrective actions and procedures have been developed by Airbus Industrie. This should enable the operators to evaluate the existing Service Bulletins and place orders for mod kits accordingly.

Recommendations, and in particular the decontamination procedures, indicated in the Aircraft Maintenance Manual and Service Information Letters should be incorporated in Job Cards and maintenance training curricula. Their application will certainly increase passenger and crew comfort and alleviate the risk of costly and repetitive flight interruptions.

18
FAST / NUMBER 10
This article describes the disciplines and procedures used for the development of scheduled maintenance programmes. Principles of decision-logic procedures for systems and structure, and the work required to implement these procedures for a new civil aircraft project are examined together with the interfaces between the maintenance programme development activity and aircraft certification. Organisational aspects are reviewed including the roles of the various working bodies concerned with maintenance programme development and the planning of the work.


**EVOLUTION OF DECISION-LOGIC TECHNIQUES**

Maintenance programmes have undergone dramatic changes over the last three decades. Thirty years ago it was common for a jet transport to have some 300 components subject to "hard time" overhaul and C-checks and D-checks at around 250 flying hours and 2500 flying hours respectively. Today there are few items that require overhaul at pre-determined intervals and intervals for C and D-checks have increased more than tenfold.

The realisation that many types of failure could not be prevented, however intensive the maintenance, and the difficulty of eliminating uncertainty has placed emphasis during design in preventing failures from affecting safety. This has led to the development of decision-logic techniques for evaluating maintenance programmes.

Largely through FAA/Industry reliability studies a great deal was learned about the conditions required for effective maintenance, and in 1965 a decision-diagram technique was devised by a Maintenance Steering Group (MSG) and later used to develop the initial maintenance programme for the B747. This technique was generally known as MSG1 and subsequent improvements led, in 1970, to MSG2 : Airline/Manufacturer Maintenance Programme Planning Document which was used for the L1011 and DC-10 programmes. A similar document, called EMMSG and prepared in Europe, offered a more rigorous structural analysis method. It was used for Concorde and the A300.

In 1979 the ATA/MSG task force undertook a detailed examination of MSG2 and in 1980 a major revision to the decision-logic was introduced as MSG3. More recently, after extensive experience in using MSG3 for the jet transports of the 1980's further refinements resulted in MSG3 Revision 1.

**MSG3 PRINCIPLES**

MSG3, like its predecessors, gives decision-logic flow paths to provide a rational procedure for task definition, applicability and effectiveness. The overall objective being to develop a set of initial scheduled maintenance requirements which will maintain the inherent levels of safety and reliability at the minimum practical costs of ownership.

MSG3 provides separate analysis methods for systems and powerplant, structure and aircraft zones.

**Systems and powerplant method**

The systems and powerplant method commences with a listing of Maintenance Significant Items (MSIs) which are items whose failure could affect safety, may be undetectable during operation, or could have a significant operational or economic impact. This is most conveniently done by consulting the ATA 100 breakdown which allocates numerical references to each system, sub-system and component. The MSI functions, functional failures, failure effects and failure causes are then determined for detailed evaluation.

The approach taken is then to provide a logic path for each functional failure and failure cause so that a judgement may be made as to the necessity of a task. This decision logic has two levels:

- level 1 (figure 1) requires the evaluation of each functional failure to determine the effect category; i.e. safety, operational, economic, hidden safety or hidden non-safety;
- level 2 (figure 2) then takes the failure causes for each functional

---

**Figure 1**

**MSG3 principles - Systems and powerplant logic - Level 1**

**Is the occurrence of a functional failure evident to the operating crew during the performance of normal duties?**

- **YES**
  - Does the functional failure or secondary damage resulting from the functional failure have a direct adverse effect on operating safety?
    - **YES**
      - Does the functional failure have a direct adverse effect on operating safety?
        - **YES**
          - Safety effects: Task(s) required to assure safe operation
        - **NO**
          - Operational effects: Task desirable if risk reduced to an acceptable level
        - **Safety effects**
          - Task(s) required to assure the availability necessary to avoid safety effects of multiple failures
    - **NO**
      - Operational effects: Task desirable if risk reduced to an acceptable level
        - **YES**
          - Economic effects: Task desirable if cost is less than repair costs
        - **NO**
          - Non-safety effects: Task(s) desirable to assure the availability necessary to avoid economic effects of multiple failures

- **NO**
  - Does the combination of a hidden functional failure and one additional failure of a system related or backup function have an adverse effect on operating safety?
    - **YES**
      - Safety effects: Task(s) required to assure the availability necessary to avoid safety effects of multiple failures
    - **NO**
      - Operational effects: Task desirable if risk reduced to an acceptable level
<table>
<thead>
<tr>
<th>Safety effects</th>
<th>Operational effects</th>
<th>Economic effects</th>
<th>Safety effects</th>
<th>Non-safety effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task(s) required to assure safe operation</td>
<td>Task desirable if risk reduced to an acceptable level</td>
<td>Task desirable if cost is less than repair costs</td>
<td>Task(s) required to assure the availability necessary to avoid safety effects of multiple failures</td>
<td>Task(s) desirable to assure the availability necessary to avoid economic effects of multiple failures</td>
</tr>
</tbody>
</table>

**Lubrication/Servicing**
- **YES**
- **NO**
  - Is a lubrication or servicing task applicable and effective?

**Inspection/functional check**
- **YES**
- **NO**
  - Is an inspection or functional check to detect degradation of function applicable and effective?

**Restoration**
- **YES**
- **NO**
  - Is a restoration task to reduce failure rate applicable and effective?

**Discard**
- **YES**
- **NO**
  - Is there a task or combination of tasks applicable and effective?

**Task/combination most effective must be done**
- **YES**
  - Redesign is mandatory
- **NO**
  - Redesign may be desirable

**Task/combination most effective must be done**
- **YES**
  - Redesign is desirable
- **NO**
  - Redesign may be desirable
failure into account for selecting the specific tasks.

At level 2, regardless of the first question "Lubrication/Servicing" the next question must be asked in all cases. When following the evident safety or hidden safety effects path all subsequent questions must be asked. In the other categories, subsequent to the first question, a Yes answer will allow exiting the logic. The logic is arranged so that a No answer leads to a more stringent and/or costly route.

Inspection check intervals are selected through engineering judgement and experience.

**Structures Method**

The structures analysis method covers all load carrying members including wings, fuselage, pylon, empennage, engine mounts, landing gear, flight control surfaces and related points of attachment. Structural Significant Items (SSIs) are first determined. They are details, elements or assemblies which contribute significantly to carrying flight, ground, pressure or control loads and whose failure could affect the structural integrity necessary for safety. These items are then assessed against environmental, accidental and fatigue damage sources to determine inspection level (general visual, detailed or special detailed), inspection interval and the appropriateness of inclusion in fleet leader and age exploration programmes.

For the A310, A300-600 and A320 programmes each SSI was analysed in the sequence: fatigue damage, environmental damage and accidental damage.

- Fatigue damage results from cumulative loading and intervals are expressed in flight cycles. For systematic damage a threshold for first inspection can normally be justified as a factor of the mean fatigue life. The inspection intervals are determined from the time the damage grows from detectable to critical size where the structure will carry its limit load (figure 3). The detectable damage size is related to inspection level, e.g. general visual, detailed or special detailed (employing non-destructive testing techniques), which in turn has an influence on the inspection interval owing to the time it takes for the damage to grow from detectable to critical size.

- The Environmental Damage Analysis examines each SSI for susceptibility of each type of corrosion in consideration of materials, design features,
protective treatments and the environment to which the item is likely to be subjected. A numerical rating is applied to each aspect, which when combined through a rating matrix gives the appropriate inspection interval in calendar time (figure 4). The corrosion type is then classified as systematic or random to determine if sampling or full fleet inspections are required.

- The Accidental Damage Analysis assesses susceptibility to manufacturing defects or inflicted damage and their consequences classified as fatigue and/or corrosion which are then assessed for their impact on the fatigue and environmental damage analyses previously conducted.

  - Fleet Leader (for fatigue) and Age Exploration (for corrosion) programmes for timely damage detection may be appropriate, and concern aircraft selected from those having the highest operating usage/age.

  **Zonal Method**

The zonal programme requires a review of each aircraft zone to evaluate general visual inspections for the purpose of detecting obvious damage to installations and structure. The aircraft is divided into external and internal zones as defined by ATA 100 and subjected to detailed review in consideration of accessibility, density of components installed, "traffic" through the zone and environmental conditions. Inputs from systems and structures working groups are also taken into account. All inspection requirements are then consolidated and inspection intervals assigned.

**INTERFACE WITH CERTIFICATION REQUIREMENTS**

The particular certification requirements concerning maintenance programmes are FAR/JAR 25.1529 and FAR/JAR Appendix H, Instructions for Continued Airworthiness, FAR/JAR 25.571, Damage Tolerance and Fatigue Evaluation and FAR/JAR 25.1309, Equipment, Systems and Installations. Appendix H concerns Maintenance Instructions, including an inspection programme, and Airworthiness Limitations such as mandatory replacement times, structural inspection intervals and related procedures approved under FAR/JAR 25.571.

Aircraft certificated under the requirements of FAR/JAR 25.1309 may make use of numerical probabilities in demonstrating an acceptable level of reliability by ensuring the correct relationship between probability and severity of effects of systems failures. Compliance with FAR/JAR 25.1309 is often dependent on maintenance tasks, usually operational tests to check the availability of hidden functions.

The analysis techniques are more rigorous than MSG3 and involve complex reliability models.

FAR/JAR 25.571 requires evaluation of the structure to show that catastrophic failure conditions due to fatigue, corrosion or accidental damage will be avoided, and provision of the necessary inspections and procedures.

Throughout the maintenance programme development activity close liaison with the design groups is essential to ensure that the maintenance programme, derived through MSG3, is compatible with the requirements de-
rived through the Type Certification process.

Maintenance tasks derived from FAR/JAR 25.1309 are candidates for Certification Maintenance Requirements (CMR's) which originated from a FAA order designed to maintain the certification requirements. CMR's are mandatory.

The tasks arising from FAR/JAR 25.571 are candidates for the Airworthiness Limitations Section but are not finalised until the fatigue test programme is completed.

DEVELOPING THE A320 MAINTENANCE PROGRAMME

The organisation to carry out the maintenance programme development for a specific aircraft type is usually staffed by representatives of the airline operators purchasing the equipment, the prime manufacturers of the airframe and power plants and the Regulatory Authorities of the country of manufacture.

The principle working bodies are:
- the Maintenance Review Board comprising the regulatory authorities to approve the final programme,
- the joint airline/manufacturer Steering Committee to direct the activities, and
- joint airline/manufacturer Working Groups to evaluate the aircraft and determine the requirements (figure 5).

For the A320 the formal maintenance programme development activity started thirty months before entry into service with the formation of the joint airline/manufacturer Steering Committee. First tasks were to establish the policy and procedures, set the initial check interval framework and prepare the allocation of work and planning for the Working Groups.

Six Working Groups were formed to cover the complete aircraft, with the work allocated as follows:
- WG1, for Flight controls, Hydraulic Power and Landing Gear.
- WG2, for Air Conditioning, Equipment/Furnishings, Ice and Rain, Oxygen, Water Waste, Doors and Windows.
- WG3, for Fuel, APU, Powerplants (CFM56 and V2500).
- WG5, for Structure.
- WG6, for Zonal.

The Working Group activity commenced some eighteen months prior to entry into service in order to publish a first programme six months before entry into service to cover early operation. The programme was refined to take account of any changes during flight test and finalised at the time of Type Certification.

Participating organisations involved in the development activities were: Airbus Industrie and Partner Firms, Powerplant manufacturers, European and United States Regulatory Authorities, Adria, Air France, Air Inter, Ansett, British Caledonian, GATX, Lufthansa, Nippon Airline System, Northwest Airlines and Pan American.

Developing this initial programme required some 30 man-years of manufacturer's effort and entailed a total of 42 joint industry meetings of between two and five days duration. A total of 200 Maintenance Significant Items and 440 Structural Significant Items were analysed according to MSG3 methods. All resulting requirements are contained in the DGAC and the FAA approved Maintenance Review Board (MRB) Documents.

The basic check intervals for the A320 are:
- Service check (weekly)
- A-check (350 flight hours)
- C-check (15 months)
- Zonal (4 and 8 years)
- Structure/fatigue (threshold 20,000 flight hours) (interval 7,500 and 15,000 flight hours)
- Structure/environment (threshold 4 and 8 years) (interval 4 and 8 years)

The A320 Structural Inspection Programme will be further reviewed in 1993 after analysis of the fatigue test and teardown results.

SERVICE EXPERIENCE

It should be recognized that the initial maintenance programme as given by the MRB Document is based on the best information available before the aircraft enters service. Information only becomes available about the actual interaction of the equipment with the operating environment after entry into service, and adjustments will be both necessary and desirable.

The bases for maintenance programme adjustments are:
- an effective system for monitoring maintenance findings, and reporting those which are significant to the manufacturer,
- an effective reliability programme,
- differences between actual utilisation and the assumptions given by the MRB,
- a knowledge of manufacturer's and certification requirements.

As regards check interval extension, it is up to the operator to provide the justification to his regulatory authority based on his experience, with support if necessary from the manufacturer.

---

**Figure 5**

Procedure application - Working bodies and documents

| MSC | Maintenance Steering Committee |
| MWG1 | Maintenance Working Group |
| MWG2 | Maintenance Program Proposal |
| MWG3 | Maintenance Review Board |
| MWG4 | Maintenance Planning Document |
| MWG5 | Maintenance Approval Program |
| MWG6 | Maintenance Approval Program |
| MPP | Maintenance Planning Proposal |
| MRB | Maintenance Review Board |
| MPD | Maintenance Planning Document |
| AMP | Maintenance Approval Program |
MSG3 assists in providing information on the type of failure consequences at the origin of the system tasks and by separating the specific requirements for fatigue and environmental damage. The Certification Maintenance Requirements and Airworthiness Limitations referred to previously list those items which require a particular means of handling.

MRB documents are not at present intended to be revised on a regular basis. It is Airbus Industrie's policy to reflect maintenance programme amendments arising from service experience, and changes in aircraft configuration, through the Maintenance Planning Document, Volume 1, which represents the manufacturer’s recommended maintenance programme.

There is a regulatory requirement for the establishment of a Supplemental Structure Inspection Programme for older aircraft which requires a reassessment of the structure considering damage tolerance principles and in-service experience. Specific analysis procedures are required in order to provide flexibility in its implementation. The process is handled by a joint industry activity.

**CONCLUSION**

It is hoped that this article has provided an insight into maintenance programme development as seen by a manufacturer. The preceding text is only a summary of topics which are worthy of a more complete review but we may conclude that the disciplines which have evolved over the years are the tools leading to more realistic and effective maintenance programmes.

With ATA's concurrence, in January 1987 a group of manufacturer representatives with 'hands-on' MSG3 experience met to start the development of a proposed revision. Airbus Industrie, Aerospatiale, British Aerospace, MBB, Fokker, Boeing, Douglas, Saab and Embraer were all represented. In March 1988, after a series of meetings, MSG3 Revision 1 was completed reflecting inputs from the manufacturers, airlines and regulatory authorities.

MSG3 Revision 1 makes the process easier to apply and implement. It will be used for developing the A330/A340 Maintenance Programmes.

**MAINTENANCE AND REPAIR**

**DO YOU NEED HELP?**

*Airbus aircraft are designed for easy maintenance and repair. The benefits of these features can be seen by the ease with which Airbus aircraft enter service, have consistently high dispatch reliability and short delay times.*

by Michel PATRY, Airbus Product Support, Manager Retrofit & Repair Assistance

Since the first A300 was delivered in May 1974, followed by the A310, A300-600 and A320, requests from the operators of these aircraft for help in the form of Field Assistance, have been limited to four main categories:

- embodiment of Service Bulletins,
- assistance with heavy maintenance,
- assistance with trouble-shooting,
- assistance with major repairs.

Although there are over five hundred Airbus aircraft in service the fleet is still relatively new, with an excellent operational reliability record. Industry trends are towards airlines reducing their in-house engineering capability and becoming increasingly dependent on the manufacturers.

With increasing business activity and interest shown by the operators, Airbus Industrie Product Support has created a special department to provide field assistance. A considerable bank of experience is available on a 24 hour basis and special repair teams with repair kits and repair tools are ready for immediate dispatch.

Large aircraft parts sent on AOG by charter flight, ready for reinstallation.
EMBODIMENT OF SERVICE BULLETINS

All Airbus operators are provided with the Service Bulletins applicable to their fleet(s). Each Service Bulletin gives the installation instructions for the accompanying kit, the estimated man-hours and elapsed time for its installation, lists of tools required and the parts to be removed and installed. Most Service Bulletins are incorporated by operators without outside assistance, which is however requested on occasions. In such a case Airbus Industrie can provide on-site:

- either technicians who will advice the operator's mechanics and inspectors, or
- a team responsible for the complete embodiment, inspection and testing of the modification.

- assistance with the maintenance work, provisioning of spare parts, relations with vendors and co-ordination of turn-around programmes for components.

TROUBLE-SHOOTING

All aircraft can suffer intermittent faults which are extremely difficult to trouble-shoot. For these very special cases Airbus Industrie will provide, at customer request, special on-site assistance to help with the trouble-shooting and to restore correct system functioning. These specialists are backed-up by five million Airbus operating hours, and the support of the production line test equipment and design office knowledge. They arrive on site equipped to provide a quick solution to a problem.

AIRCRAFT REPAIR

Providing assistance to an airline to repair a damaged aircraft is one of the more visible aspects of product support. The vast majority of repairs to the aircraft structure can be accomplished using the Structure Repair Manual (SRM). This manual (one for each aircraft type) is continually updated, to provide to all concerned the experience gained with the incorporation of each repair.

DAMAGE ASSESSMENT

Generally speaking, when assistance is requested from Airbus Industrie after an incident or an accident, the repair programme is scheduled as follows. As soon as access to the aircraft is possible an inspection team assesses the damage. Following evaluation of the visible damage, the customer is advised of any additional access required for inspection, after which a detailed report of damage to structure and systems is prepared. This report does not define the cause of the accident, which is the subject of a separate investigation by the Airworthiness Authorities.

Major airports have equipment available for recovering an aircraft (getting it back on to the runway and to a place of repair) so normal operation can be resumed as quickly as possible. Airbus Industrie can provide a specialist on site to advise on lifting, shoring, supporting and towing the aircraft. It also provides Aircraft Recovery Manuals which give all the necessary information for retrieval of Airbus aircraft.

REPAIR DEFINITION

The damage report is studied by the engineering and design departments who then define the repair, choosing the most effective mixture of repair and replacement of parts. A commercial offer is then prepared.
PROPOSAL TO OPERATOR

Since the repair may be done by Airbus Industrie (Proposal 1) or the operator or a third party (Proposal 2), the commercial offer covers both cases. The contents vary as follows:

Proposal 1
Airbus Industrie takes charge of the complete repair and provides:
- repair and test procedures
- repair drawings
- work planning schedule
- parts
- specific tools
- necessary manpower

Proposal 2
Airbus Industrie provides:
- repair and test procedures
- repair drawings
- technical assistance during repair
- parts
- specific tools

THE MEANS

Manpower

The repair team is composed of specialists selected according to the section(s) of the aircraft to be repaired. It includes the mechanical, electrical and avionics systems technicians deemed necessary and also quality control inspectors. The team is large enough to ensure that work continues around the clock, to keep the aircraft grounding time to a minimum.

Repair kits/parts Provisioning

During the inspection phase, following instructions from the technical department, repair kits and additional parts are collected by the AOG department in Airspares, Hamburg, and prepared for shipment. Parts not in the spares stock are released from production stock or manufactured if lead-times are acceptable. The required material is shipped to the repair site on an AOG basis and in special charter aircraft when necessary.

Tools

Special air-transportable large repair tools, jigs, stands and gantries are complemented by special LD3 containers filled with selected tools, equipment and hardware. In addition a transportable hangar is available if this facility is desirable but not available on-site.

CONCLUSION

Airbus Industrie has made a considerable investment in documentation, tools, equipment and repair kits which are available for instant dispatch to the scene of an accident. Combined with the technical expertise of its repair organisation, and their 24-hour availability, the result is that in the event of a repairable accident airlines and insurers can have confidence that a damaged aircraft will be returned to an airworthy and revenue-earning state as soon as reasonably possible.
The potential troublemakers are the high pressure bleed valve, the fan air valve, and intermittent fault indications. The following article gives an overview of components, nacelle and aircraft modifications that have become available in recent months to improve the reliability of the engine bleed air system.

This can result in technical delays, flight cancellations, and repeated maintenance actions if a fix is not found first time. A significant reduction in malfunctions of the engine bleed system can be obtained by incorporation of the modifications listed in this article.

**ENGINE BLEED AIR SYSTEM**

Air is generally bled from an intermediate stage (IP) of the engine high pressure (HP) compressor (figure 1).

At low engine speeds, when the temperatures and pressures from the IP stage are insufficient, air is bled automatically from the last compressor stage (HP stage). HP-IP transfer is automatically selected by opening or closing of the HP bleed valve according to pressure and temperature conditions upstream of it.

The pressure of air admitted to the pneumatic system is controlled by the pressure regulator and shut-off valve commonly known as the bleed valve. This valve can also be controlled to close when a failure is detected or when air supply from the engine is not required.

Temperature control of the bleed air is achieved by the precooler (air to air heat exchanger), which is installed in the pylon. The cooling air for this precooler is bled from the engine fan and its flow rate is controlled by the fan air valve. This fan air valve is pneumatically powered (by pressure from upstream of the bleed valve).

For control and monitoring of the engine bleed air system, the pneumatic controller processes position signals of the various valves and air pressure and air temperature signals from different points of the system.

---

**Figure 1**

Engine bleed air system

- Pressure transmitters
- Precooler
- Fan air valve
- Bleed valve
- HP bleed valve
- Pneumatic controller
- IP check valve

Cockpit overhead panel
The BITE (built-in test equipment) of the pneumatic controller also enables failures and abnormal functions to be stored during flight, to facilitate maintenance.

**COMPONENT MODIFICATIONS**

### High pressure bleed valve

Contamination and overheating have been observed on most high pressure bleed valves (HPBV) returned to the manufacturer for repair and overhaul. Such damage could result in the valve not opening. The following improvements have been developed:

- Utilisation of materials with greater resistance to high temperature,
- Replacement of the wire mesh filter by a trailing edge probe to reduce ingestion of contaminants,
- Installation of a servo pressure limiter to prevent high servo pressure and high servo flow. The corresponding Garrett Service Bulletins are listed in table 1.

Installation of an additional nozzle on the cooling system of the engine nacelle, as shown in figure 2, is also proposed to ventilate the HPBV servo regulator with cold fan air. The Service Bulletins for different engines are listed in table 2.

### Fan air valve

Typical findings on fan air valves (FAV) sent back to the manufacturer have been valve non opening due to breakage of the actuator linkage, and incorrect position indication due to wear of the position switch adapter. These malfunctions could result in bleed air over-temperature or nuisance BITE indications. The necessary improvements have been developed and are available under the Service Bulletins listed in table 1.

### MODIFICATIONS TO MONITORING AND CONTROL CIRCUITS

Other possible causes for HP BLEED VALVE and 'BLEED VALVE' fault warnings are malfunctions of the control and monitoring circuits. Such nuisance fault warnings include:

- Leakage or blockage of a sense line,
- Intermittent fault in the aircraft's wiring,
- Too fine and therefore penalising tolerances in the fault logic.

The following improvements have been developed to reduce the occurrence of these malfunctions.

### Sense lines

Depending on the affected sense line, leakage or blockage can cause an over pressure or an over temperature malfunction with a BLEED VALVE fault warning or an abnormal control of the HPBV leading to an 'HP VALVE' fault warning.

Leakage usually affects the flexible sense lines. Several improvements such as new routing and additional clamping have already been made available for several sense line installations; however, the most common reason for sense line damage is still incorrect installation.

Two spanners must be used to connect a flexible sense line, one to prevent the line from turning and the other to turn the unions. Not adhering to this procedure inevitably results in twisted and ruptured lines.

Rigid pipes do not suffer from this problem and have recently been proposed to replace the flexible sense lines downstream of the bleed valve. However rigid pipes are not a solution for all sense line applications, so the two-spanner procedure for connecting flexible pipes should be promoted among the mechanics.

Most sense lines are routed in warm areas of the nacelle and pylon, where they are unlikely to be affected by the obstructive effects of condensation, water accumulation and freezing. Pressure transmitters which sense air pressure for HPBV switching and bleed pressure indication are currently located in the leading edge of the wing where freezing temperatures have been recorded. A modification to relocate them with shorter sense lines in a warmer area in the pylon is now available. The Service Bulletins are listed in table 3.

### Electrical wiring

Repellent 'HP VALVE' fault warnings are attributable to intermittent position indication caused by breakage of electrical wires. Two potential wiring inter-
Mitticities have been identified:
- the first affects the HPBV internal wiring and is the subject of a component modification listed in table 1;
- the second affects the engine electrical harness which is sensitive to overheating and frequent connector removal/installation.

The necessary improvements have been defined to ensure long-term wiring integrity. The corresponding Service Bulletins are listed in table 2.

MONTORING AND FAULT LOGIC

Currently a ‘BLEED VALVE’ fault warning illuminates to indicate a temporary low temperature or low pressure condition. This warning is not essential when there is sufficient air to run the air-conditioning packs and the Wing Anti Ice system is not on.

Nuisance ‘HP VALVE’ fault warnings are also triggered by transient HPBV operation or intermittent electrical connections. Such a rigorous fault logic is considered too penalising to monitor pneumatic valves operating in a severe environment. The monitoring function has been modified to delay or inhibit certain fault warnings when they are not confirmed or not required, i.e., when Wing Anti Ice is off. The corresponding Service bulletins are listed in table 3.

TROUBLE SHOOTING RECOMMENDATIONS

A system malfunction not clearly identified when first reported is obviously a potential cause for further flight delay or cancellation.

Fault isolation should be accomplished using the flow charts provided in the Airbus Trouble Shooting Manual. Comprehensive descriptions of system monitoring and BITE instructions for the pneumatic controller are available in Airbus Service Information Letter (SIL) 36-011 to emphasize correct trouble-shooting procedures. Based on in-service experience, it has been proven the most effective way to trouble-shoot, provided it is carefully followed. In particular leak checks of sense lines and continuity checks of electrical wiring should not be overlooked. A summary of these recommendations has been published in a pocket size handbook called ENGINE BLEED SYSTEM TROUBLE SHOOTING GUIDELINES (ref. ST250002) and has been distributed to all Airbus Field Service stations.

CONCLUSION

Operators are encouraged to incorporate the engineering changes which have been proven effective during their evaluation campaign and initial revenue service. Obvious improvements have been achieved with the introduction of more reliable components, monitoring and control circuits. Nevertheless recognition and management of other aspects mentioned in this article, such as adequate maintenance and trouble-shooting practices, will also result in time and cost savings by reducing delay and cancellation rates.

Bearing in mind that the A310 and A300-600 will still be in service twenty years from now it is worth ordering modification kits now and planning their timely incorporation.
<table>
<thead>
<tr>
<th>LOCATION</th>
<th>TELEFAX</th>
<th>TELEPHONE</th>
<th>SITA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALGIERS</td>
<td>-</td>
<td>213 (2) 761525</td>
<td>ALGTZAH</td>
</tr>
<tr>
<td>AMMAN</td>
<td>962 (8) 51199</td>
<td>962 (8) 51284</td>
<td>AMMAIRJ</td>
</tr>
<tr>
<td>AMSTERDAM</td>
<td>31 (20) 484175</td>
<td>31 (20) 485005</td>
<td>SPLITSL</td>
</tr>
<tr>
<td>ATHENS</td>
<td>30 (1) 9832479</td>
<td>30 (1) 9818581</td>
<td>ATHYEOA</td>
</tr>
<tr>
<td>BERLIN</td>
<td>37 (2) 6788397</td>
<td>37 (2) 6783311</td>
<td>SXFAIIF</td>
</tr>
<tr>
<td>BANGKOK</td>
<td>66 (2) 5311940</td>
<td>66 (2) 5311940</td>
<td>BKKZUTG</td>
</tr>
<tr>
<td>BOMBAY - AIC</td>
<td>91 (22) 6147175</td>
<td>91 (22) 6128203</td>
<td>-</td>
</tr>
<tr>
<td>BOMBAY - IAC</td>
<td>91 (22) 6124328</td>
<td>91 (22) 6124328</td>
<td>-</td>
</tr>
<tr>
<td>CAIRO</td>
<td>202 672472</td>
<td>202 672472</td>
<td>CAIESMS</td>
</tr>
<tr>
<td>DAKAR</td>
<td>221 203773</td>
<td>221 203773</td>
<td>DKRIERK</td>
</tr>
<tr>
<td>DUBAI</td>
<td>971 (4) 246073</td>
<td>971 (4) 245019</td>
<td>-</td>
</tr>
<tr>
<td>FRANKFURT</td>
<td>49 (69) 6964555</td>
<td>49 (69) 6963947</td>
<td>-</td>
</tr>
<tr>
<td>HANOVER</td>
<td>49 (511) 775630</td>
<td>49 (511) 7303293</td>
<td>HAJAIHF</td>
</tr>
<tr>
<td>HELSINKI</td>
<td>358 (0) 8186797</td>
<td>358 (0) 822768</td>
<td>HELGUAY</td>
</tr>
<tr>
<td>ISTANBUL</td>
<td>90 (1) 5735521</td>
<td>90 (1) 5740907</td>
<td>-</td>
</tr>
<tr>
<td>JAKARTA</td>
<td>62 (21) 5501943</td>
<td>62 (21) 5501993</td>
<td>-</td>
</tr>
<tr>
<td>JEDDAH</td>
<td>966 (2) 6842863</td>
<td>966 (2) 6842864</td>
<td>-</td>
</tr>
<tr>
<td>KARACHI</td>
<td>92 (21) 480604</td>
<td>92 (21) 480604</td>
<td>-</td>
</tr>
<tr>
<td>KUALA LUMPUR</td>
<td>60 (3) 7462230</td>
<td>60 (3) 7702470</td>
<td>KULBAMH</td>
</tr>
<tr>
<td>KUWAIT</td>
<td>965 (4) 742193</td>
<td>965 (4) 742193</td>
<td>KWBKLU</td>
</tr>
<tr>
<td>LAGOS</td>
<td>-</td>
<td>234 (1) 900471 Ext 117</td>
<td>LOSSOWT</td>
</tr>
<tr>
<td>LARNACA</td>
<td>357 (4) 624285</td>
<td>357 (4) 620881</td>
<td>-</td>
</tr>
<tr>
<td>LISBON</td>
<td>351 (1) 807032</td>
<td>351 (1) 807032</td>
<td>LISBICR</td>
</tr>
<tr>
<td>LJUBLJANA</td>
<td>38 (64) 21677</td>
<td>38 (64) 21677</td>
<td>LJUMMIP</td>
</tr>
<tr>
<td>LONDON (LHR)</td>
<td>44 (81) 5626785</td>
<td>44 (81) 5626786</td>
<td>LHRYWA</td>
</tr>
<tr>
<td>LOS ANGELES</td>
<td>1 (213) 6465888</td>
<td>1 (213) 6465884</td>
<td>LAXQCCO</td>
</tr>
<tr>
<td>LUTON</td>
<td>-</td>
<td>44 (582) 483826</td>
<td>LTNEMZB</td>
</tr>
<tr>
<td>MADRID</td>
<td>34 (1) 3290708</td>
<td>34 (1) 3291447</td>
<td>-</td>
</tr>
<tr>
<td>MANILA</td>
<td>63 (2) 8315444</td>
<td>63 (2) 8315444</td>
<td>-</td>
</tr>
<tr>
<td>MELBOURNE</td>
<td>61 (3) 3380281</td>
<td>61 (3) 3380283</td>
<td>MELLZAN</td>
</tr>
<tr>
<td>MIAMI</td>
<td>1 (305) 8712322</td>
<td>1 (305) 8711441</td>
<td>-</td>
</tr>
<tr>
<td>MINNEAPOLIS</td>
<td>1 (612) 7260414</td>
<td>1 (612) 7260431</td>
<td>-</td>
</tr>
<tr>
<td>MOGADISHU</td>
<td>-</td>
<td>00252 (1) 39692</td>
<td>-</td>
</tr>
<tr>
<td>MONTREAL</td>
<td>1 (514) 6362996</td>
<td>1 (514) 6363230</td>
<td>-</td>
</tr>
<tr>
<td>NAIROBI</td>
<td>254 (2) 822881</td>
<td>254 (2) 822171 Ext 2119</td>
<td>NBOECKQ</td>
</tr>
<tr>
<td>NEW DELHI</td>
<td>91 (11) 3295373</td>
<td>91 (11) 3295378</td>
<td>DELEANIC</td>
</tr>
<tr>
<td>NEW YORK (JFK)</td>
<td>1 (718) 6568635</td>
<td>1 (718) 6322225</td>
<td>-</td>
</tr>
<tr>
<td>PARIS (CDG)</td>
<td>33 (1) 4864248</td>
<td>33 (1) 4864223</td>
<td>CDGASAF</td>
</tr>
<tr>
<td>PARIS (ORY)</td>
<td>33 (1) 49780185</td>
<td>33 (1) 49780237</td>
<td>ORYASAF</td>
</tr>
<tr>
<td>PARIS (ORY)</td>
<td>33 (1) 46750943</td>
<td>33 (1) 46750949</td>
<td>ORYAIIBT</td>
</tr>
<tr>
<td>PORT-MORESBY</td>
<td>675 213254</td>
<td>675 273255</td>
<td>POMBPEX</td>
</tr>
<tr>
<td>ROME</td>
<td>39 (6) 6829077</td>
<td>39 (6) 6011564</td>
<td>FCOYSAZ</td>
</tr>
<tr>
<td>SAO PAULO</td>
<td>55 (11) 618002</td>
<td>55 (11) 5337011 Ext 361</td>
<td>GIGBSRG</td>
</tr>
<tr>
<td>SEOUL</td>
<td>82 (2) 6643219</td>
<td>82 (2) 6654417</td>
<td>SELXSKE</td>
</tr>
<tr>
<td>SHANGHAI</td>
<td>-</td>
<td>86 (21) 4328767</td>
<td>-</td>
</tr>
<tr>
<td>SINGAPORE</td>
<td>65 (5) 425380</td>
<td>65 (5) 455027</td>
<td>-</td>
</tr>
<tr>
<td>TAPEI</td>
<td>886 (3) 3834718</td>
<td>886 (3) 3834410</td>
<td>-</td>
</tr>
<tr>
<td>TOKYO (HND)</td>
<td>81 (3) 7476174</td>
<td>81 (3) 7476004</td>
<td>-</td>
</tr>
<tr>
<td>TORONTO</td>
<td>1 (416) 6711137</td>
<td>1 (416) 6711256</td>
<td>YYYMAWD</td>
</tr>
<tr>
<td>TULSA</td>
<td>1 (918) 8322581</td>
<td>1 (918) 8323227</td>
<td>HDQMRAA</td>
</tr>
<tr>
<td>VIENNA</td>
<td>43 (222) 77703235</td>
<td>43 (222) 77703688</td>
<td>-</td>
</tr>
<tr>
<td>ZURICH</td>
<td>41 (1) 8102383</td>
<td>41 (1) 8127727</td>
<td>ZRHZESR</td>
</tr>
</tbody>
</table>
Recent advances in static testing have shown the need for more accurate positioning of the static loads along the wing. The old method of placing the production staff, carefully graded for decreasing weight, from the fuselage centre line out along the main spar has given way to careful placing of sandbags. This significant development has made the ultimate load (breakage) test much more acceptable to the personnel involved!

The upturned wing of a Dewoitine D-27 single seat fighter statically tested under a charge corresponding to a coefficient of 20°.

One hundred men load the wing of a Rohrbach-Romar flying-boat which had an unsupported wing span approaching 40 metres (1928).
WHEN MAINTENANCE WANT TO KNOW THEY DON'T EVEN NEED TO ASK.

The new Airbus A340 features an on-board maintenance computer that displays details of any malfunction via the Centralised Fault Display System (CFDS). Print-outs too can be provided and the information can even be telemetered direct to the aircraft's destination.

As a result maintenance crews are made aware of the tasks they'll need to perform even before the aircraft has landed.

All this has got to be good news for airlines. Because in the search to reduce downtime they couldn't ask for more by way of timesaving innovations.